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POTENTIAL BENEFITS FROM THE USE OF JP-8 FUEL IN MILITARY GROUND EQUIPMENT

INTERIM REPORT
BFLRF No. 249

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Contract No. DAAK70-87-C-0043

February 1989

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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS None
2a. SECURITY CLASSIFICATION AUTHORITY N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) BFLRF No. 249	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Belvoir Fuels and Lubricants Research Facility (SwRI) 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Southwest Research Institute San Antonio, Texas 78228-0510	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U.S. Army Belvoir Research, Development and Engineering Center 8b. OFFICE SYMBOL (If applicable) STRBE-VF	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DAAK70-87-C-0043, WD 7
8c. ADDRESS (City, State, and ZIP Code) Fort Belvoir, VA 22060-5606	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 63001D PROJECT NO. 1L263001D150 TASK NO. 07(7) WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)

Potential Benefits From the Use of JP-8 Fuel in Military Ground Equipment (U)

12. PERSONAL AUTHOR(S) Montemayor, Alan F., and Stavinoha, Leo L., and Lestz, Sidney J., and LePera, Maurice E. (Belvoir RDE Center)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Interim	FROM Oct 87 TO Feb 89	1989 February	30

16. SUPPLEMENTARY NOTATION

[illegible]

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Benefits, Fuel Additives, CI Engines, Exhaust Emissions, Fuels, Aviation Fuels, Emission, Particulates, Kerosene, Diesel Fuel, Sulfur, Logistics

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The United States Department of Defense (DOD) is moving toward the use of JP-8 as a single fuel for use in Europe. Many potential benefits are associated with the exclusive use of JP-8 in U.S. DOD equipment. This study briefly discusses these benefits and provides references for further study. Some of the benefits associated with the use of JP-8 will be immediate, and some will require time to be appreciated. Some benefits will accrue during peacetime operations, and some will be most apparent during times of conflict. As JP-8 finds increasing use in field tests and conversions of military bases, there will no doubt be problems that arise alongside the benefits. Careful weighing of the benefits and problems will ultimately lead to optimal usage of fuel resources and, hopefully, increased readiness. The main benefits associated with the use of JP-8 in military ground equipment are simplified logistics, increased readiness, reduced exhaust emissions, and better lubricant life. The information contained in this report is intended to delineate those areas where the use of JP-8 will prove beneficial and alert those personnel that will be affected by the change.

(Cont'd)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Mr. T.C. Bowen	22b. TELEPHONE (Include Area Code) (703) 664-3576 22c. OFFICE SYMBOL STRBE-VF

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

18. **SUBJECT TERMS** (Cont'd)

Flow
Viscosity

19. **ABSTRACT** (Cont'd)

Introduction of JP-8 into the military system should proceed. The most useful demonstration programs will be operations that involve joint operations of forces to include Army ground and aviation activities. These operations should be monitored for benefits as well as possible problems and the lessons learned applied accordingly. Jet engine fuels; Kerosene; [illegible]ilities; Diesel fuels; Compression/ignition engines; [illegible]/exhaust emissions/particulates; Logistics; Military ground/Combat vehicles. (EDC)

EXECUTIVE SUMMARY

Problems and Objectives: Currently, the Department of Defense (DOD) provides a wide range of fuels for its compression ignition engines. These fuels include diesel grades DF-A, DF-1 and DF-2, NDF and aviation jet kerosene grades JP-5 and JP-8. The choice of which fuel to use depends upon the type of service, ambient conditions, availability of fuel in the locale, and cost. Because of the diversity of fuels and requirements, a substantial fuel logistics burden exists in the DOD. Recently, the "One-Fuel-Forward" concept has emerged as a desirable goal among the NATO nations. This concept would move the tactical fleet toward the use of one fuel. The program reported here involved researching and analyzing the potential benefits to the U.S. and NATO military that would arise from using JP-8 as the primary tactical fuel.

Importance of Project: In making a decision of such significance, the merits of using the candidate fuel as the primary battlefield fuel must be carefully considered. This effort addresses those benefits in order to permit a cautious and conservative change-over to a single fuel.

Technical Approach: In recent years, DOD interest in the use of JP-5 and JP-8 as fuel for compression ignition (CI) engines has increased. This interest was based on the good low-temperature properties of the fuels as well as the logistics benefits of using the same fuel for aircraft and ground equipment. As a result, numerous investigations of the use of JP-5 and JP-8 in CI engines were conducted. A literature search involving these programs and other related literature was conducted, and the potential benefits associated with JP-8 as opposed to DF-2 were categorized and evaluated.

Accomplishments: This study discusses the benefits of JP-8 fuel as the single fuel for NATO's ground equipment. References are provided for further study. As a result of this study, it is recommended that introduction of JP-8 as the primary military ground equipment fuel in Europe should continue, and these operations should be carefully monitored for benefits as well as possible problems.

Military Impact: The main benefits that would accrue to the military with the use of JP-8 as the exclusive fuel for NATO's military fleet are simplified logistics, reduced lubricant degradation, reduced exhaust emissions, and increased readiness. This report has documented these potential benefits and has provided references for further study. With this information, military personnel will have additional data on which to base an informed decision concerning the introduction of JP-8 as the single fuel for the battlefield.

FOREWORD

This work was conducted at the Belvoir Fuels and Lubricants Research Facility (SwRI), Southwest Research Institute, under DOD Contract No. DAAK70-87-C-0043. The project was administered by the Fuels and Lubricants Division, Materials, Fuels and Lubricants Laboratory, U.S. Army Belvoir Research, Development and Engineering Center, Fort Belvoir, Virginia 22060-5606, with Mr. T.C. Bowen, STRBE-VF, serving as Contracting Officer's Representative. This report covers the period of performance from October 1987 to February 1989.

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I. INTRODUCTION AND BACKGROUND

The United States Department of Defense (DOD) currently purchases a wide range of fuels for its compression ignition (CI) engines. These fuels include diesel grades DF-A, DF-1 and DF-2, NDF, and aviation jet kerosene grades JP-5 and JP-8.(1-4)* The choice of which fuel to use depends to a large extent upon the type of service, ambient conditions, availability of the fuel in the locale, and cost. Different engines have different fuel requirements, and different missions may well demand different fuels for the same engine. Because of the diversity of fuels and requirements, a substantial fuel logistics burden exists in the DOD. Sudden changes in ambient conditions or mission requirements may necessitate a change in fuel that may not be quickly supportable by the supply system. This difficulty was demonstrated in the winter of 1981-82 when diesel-fueled ground equipment in Europe had severe startability problems caused by fuel wax plugging the engine fuel filters as well as nozzle plugging problems.(5) These problems were the result of the cloud point of the standard NATO diesel fuel in combination with a sudden (lower than expected) cold front to which the fuel supply system could not react.

For many years, the U.S. Navy has been using JP-5 to fuel planes and helicopters in shipboard and land-based service. JP-5 was used rather than JP-4 because the higher flash point requirement of JP-5 makes shipboard handling of the fuel safer in the event of a spill or crash. Since the JP-5 was already stored aboard ships and at Navy bases, it was very efficient to run diesel engines on it rather than provide separate tankage for DF-2. A series of tests were performed at Port Hueneme, CA in the mid 1960s to determine the impact of using JP-5 in diesel engines. The results of the study indicated that JP-5 was an acceptable alternate to DF-2 for the diesel engines then assigned to the Naval Construction Forces.(6-8) Use of JP-5 in lieu of DF-2 resulted in a reduced logistics burden in shipboard and remote locations.

During the early 1970s, Army agencies were requested to consider the use of JP-5 as an alternate fuel for all equipment powered by CI engines. Based on the aforementioned work at Port Hueneme, surveys of engine and component manufacturers, short-term testing conducted by the Army, and a comprehensive knowledge of military engine fuel requirements, the Army subsequently approved JP-5 as an alternate to VV-F-800 fuels.(9)

* Underscored numbers in parentheses refer to the list of references at the end of this report.

In subsequent years, substantial interest in the DOD has existed in the use of JP-5 and JP-8 as CI fuels. This interest was based on the good low-temperature properties of the fuels (low cloud point) as well as the logistics benefits of using the same fuel for aircraft and ground equipment. Because of this interest, numerous investigations of the use of JP-5 and JP-8 in compression-ignition engines were conducted. Bowden, Owens, and LePera (10) have provided a review report including an annotated bibliography of 23 references consisting of technical notes, letters, letter reports, and interim reports, on the subject of using aircraft turbine fuels JP-5 and JP-8 in diesel engines.

Recently the single fuel on the battlefield concept has captured the attention of many people in the DOD. Essentially this concept would move the tactical fleet toward the use of one fuel. This concept was put into writing in a DOD Directive dated March 11, 1988 entitled Fuel Standardization.(11) The North Atlantic Treaty Organization (NATO) allies are also moving toward the use of JP-8 as the single fuel for land-based air and ground forces.(12) The potential for logistics benefits is large considering the amount of fuel used by the DOD and NATO and the amount of fuel-burning equipment fielded. JP-8 has emerged as the logical fuel to implement a single fuel on the battlefield concept because of its properties and availability. The purpose of this report is to document potential benefits that may arise due to the use of JP-8 in DOD CI engines.

This report addresses the potential benefits associated with the use of JP-8 and is intended as a starting point for detailed studies of fuel and logistics effects. It is recognized that there may be detriments associated with JP-8 use, and there may also be resistance to the changeover to JP-8. However, open discussion between supporters and dissenters will make the changeover to JP-8 a cautious and conservative one. Since the U.S. security depends on the military personnel and equipment stationed throughout the world, any change to JP-8 should be implemented with caution. It is hoped that the benefits discussed in this report will be weighed against the detriments from other sources and policy formulated accordingly.

II. DISCUSSION

For purposes of comparison, DF-2 is used throughout this discussion since DF-2 is the primary fuel that most CI engines have been designed to utilize. The potential benefits ascribable to the use of JP-8 in DOD CI engines can be divided into two general

categories, which have some degree of overlap. The first category is benefits of JP-8 use relative to DF-2. These benefits arise directly from the use of JP-8 in lieu of DF-2. Examples of benefits from the use of JP-8 rather than DF-2 are reduced engine wear, reduced corrosion of internal fuel-wetted components, and better low-temperature operability.

The second category of benefits discussed includes those benefits arising from the use of only one fuel rather than two or more different fuels. These benefits are generally thought of as logistical benefits, although this is not always true. Examples are the reduced possibility of equipment mis-fueling (note that this is not a logistics benefit per se), fewer fuel changeovers in multiproduct pipelines (a logistics benefit), a reduction in the amounts of pipeline interface mixtures to dispose of, the many simplifications due to handling one fuel, and the advantages in handling JP-8 rather than current fuels.

In order to discuss the impacts of fuels on equipment, it must be realized that the designations JP-8 and DF-2 do not describe actual fuels. Rather, these fuel specifications describe two ranges of fuel properties against which actual fuels are procured. TABLE 1 lists fuel types that are discussed in this report, along with their NATO designations, military or civilian specification designations, and the common name that will be used throughout this report. TABLE 2 contains specified fuel properties associated with DF-A, DF-1 and DF-2, NDF, JP-5 and JP-8. Fig. 1 contains a graphical representation of the boiling ranges of these fuels and serves as a good comparison between fuels.

III. BENEFITS OF JP-8 RELATIVE TO DF-2

A. Low-Temperature Effects

The most obvious benefit that can be ascribed to the use of JP-8 relative to DF-2 is low-temperature operability. Since JP-8 does not have the high boiling fractions of DF-2 (see Fig. 1), its cloud point and freezing point are substantially lower. U.S. Federal Specification VV-F-800D currently specifies the allowable cloud point for grades DF-1 and DF-2 according to the anticipated low ambient temperature at the location of intended use. A survey of commercial diesel fuels in the United States in 1987 indicated that the range of cloud points for DF-1 was -50° to -26°F and for DF-2 was -20° to

TABLE 1. Fuel Designations, Codes, and Specifications

Common Name	NATO Designation	NATO Title	U.S. Military/Federal Specification	U.S. Civilian Standard
JP-4	F-40	Turbine Fuel, Aviation, Wide-Cut Type + FSII (S-748)	MIL-T-5624 [illegible]ne Fuel, Aviati[illegible] Grade JP-4	ASTM D 1655 Turbine Fuel, Jet B
JP-8	F-34	Turbine Fuel, Aviation, Kerosene Type + FSII (S-748)	MIL-T-83133 Turbine Fuel, Aviation, Kerosene, Grade JP-8	NE*
Jet A-1	F-35	Turbine Fuel, Aviation, Kerosene Type	MIL-T-83133 Turbine Fuel, Aviation, Kerosene, Grade JP-8 Plus Grade F-35	ASTM D 1655 Turbine Fuel, Jet A-1
JP-5	F-44	Turbine Fuel, Aviation, High-Flash Type + FSII (S-1745)	MIL-T-5624 Turbine Fuel, Aviation, Grade JP-5	NE
Kerosene	F-58	Kerosene	NE	ASTM D 3699 Kerosene
DF-2	NE	NE	VV-F-800 Fuel Oil Diesel, Grade DF-2 "CONUS" only	ASTM D 975, Diesel 2-D
DF-2	F-54	Diesel Fuel, Military	VV-F-800 Fuel Oil, Diesel, Grade DF-2 (OCONUS)	NE
"M1 Fuel"	F-65	"Winter Fuel Blend," 1 Part F-54 with 1 Part Either F-34 or F-44	NE	NE
2-D	NE	NE	VV-F-800 Fuel Oil, Diesel, Grades DF-1 & DF-2 (CONUS)	ASTM D 975, Diesel 1-D & 2-D
NDF	F-76	Fuel, Naval Distillate	MIL-F-16884 Fuel, Naval Distillate	NE

* NE = No Equivalent.

Note: Additional data concerning mobility fuels is available in the "1987 Abbreviated Guide for Equipment Developers and Users of Mobility Fuels," published by Belvoir RDE Center.(14)

TABLE 2. Comparative Fuel Properties Related to Diesel Engine Performance

Properties	VV-F-800D				MIL-F-16884H	MIL-T-5624M	MIL-T-83133B
	DF-A	DF-1	DF-2	DF-2 (OCONUS)*	NDF	JP-5	JP-8
Flash Point, °C, min	38	38	52	56	60	60	38
Cloud Point, °C, max	-51	**	**	13	-1	NR	NR
Pour Point, °C	Rpt	Rpt	Rpt	18	-6	NR	NR
Freezing Point, °C, max	NR	NR	NR	NR	NR	-46	[illegible]
Kinematic Viscosity at 40°C, cSt	1.1 to 2.4	1.3 to 2.9	1.9 to 4.1	1.3 to 5.0(A)	1.7 to 4.3	NR(1.50)(B)	NR([illegible])(B)
Kinematic Viscosity at -20°C, cSt, max	NR	NR	NR	NR	NR	8.5	8.0
Distillation, °C							
10% recovered, max	NR	NR	NR	NR	NR	205	205
20% recovered, max	NR	NR	NR	NR	NR	Rpt	Rpt
50% recovered, max	Rpt	Rpt	Rpt	NR	Rpt	Rpt	
90% recovered, max	288	288	338	357	357	Rpt	Rpt
End Point, max	300	330	370	370	385	290	300
Residue, vol%, max	3	3	3	3	3	1.5	1.5
Carbon Residue on 10% Bottoms, wt%, max	0.10	0.15	0.35	0.2	0.20	NR	NR
Sulfur, mass%, max	0.25	0.50	0.50	0.30	1.00	0.40	0.30
Cu Corrosivity							
3 hr at 50°C, max	3	3	3	1	NR	NR	NR
2 hr at 100°C, max	NR	NR	NR	NR	1	1	1
Ash, wt%, max	0.01	0.01	0.01	0.02	0.005	NR	NR
Accelerated Stability, mg/100 mL, max	1.5	1.5	1.5	1.5	1.5	NR	NR
Neutralization Number, mg KOH/g, max	0.03	NR	NR	0.1	0.3	0.015	0.015
Particulate Contamination, mg/L, max	10	10	10	10	NR	1.0	1.0
Cetane Number, min	40	40	40	45	45	NR([illegible]2.3)(B)	NR(44.9)(B)
Net Heat of Combustion, MJ/kg, min	NR	NR	NR	NR	NR	42.6	42.8
Net Heat of Combustion, Btu/gal.	NR	NR	NR(130,575)(B,C)	NR(127,776)(B,C)	NR	NR(125,96[illegible](B,C)	NR(123,138)(B,C)

* Meets all requirements of NATO Code F-54 Guide Specifications
** Specified according to anticipated low ambient temperature at use location.
NR = No Requirement.
(A) Kinematic Viscosity values given are equivalent to NATO requirement of 1.8 to 9.5 cSt at 20°C.
(B) Average value from Reference No. 21.
(C) Net Heat of Combustion estimated from property relationships.

30°F.(13) The specification limit for the freezing point of JP-8 is -47°C (-53°F) maximum (see TABLE 2). The cloud-point and freeze-point tests (ASTM D 2500 and D 2386, respectively) measure different fuel properties, but the numbers are often close and typically do not vary more than 10 degrees F from one another. The lower freezing point of JP-8 indicates that the use of JP-8 should eliminate fuel flow problems (filter plugging, failure to pump, screen waxing) and the associated startability problems down to -53°F. Use of DF-2, however, could cause problems starting at temperatures as high as 30°F. Use of DF-1 could cause problems at temperatures as high as -26°F. Only DF-A, with a cloud-point specification maximum of -51°C (-60°F), would perform better than the JP-8 in extremely cold environments.

The boiling range of JP-8 is lower than that of DF-2 (see TABLE 2 and Fig. 1). Distillation range is measured by one of two methods, ASTM D 86 (Distillation of Petroleum Products) or ASTM D 2887 (Boiling Range Distribution of Petroleum Fractions by Gas Chromatography). The distillation temperatures at which 10, 50, and 90 percent of the fuel has evaporated are typically used to evaluate the characteristics of fuels. The 10 percent evaporated temperature is specified for JP-8 as 205°C (401°F) maximum

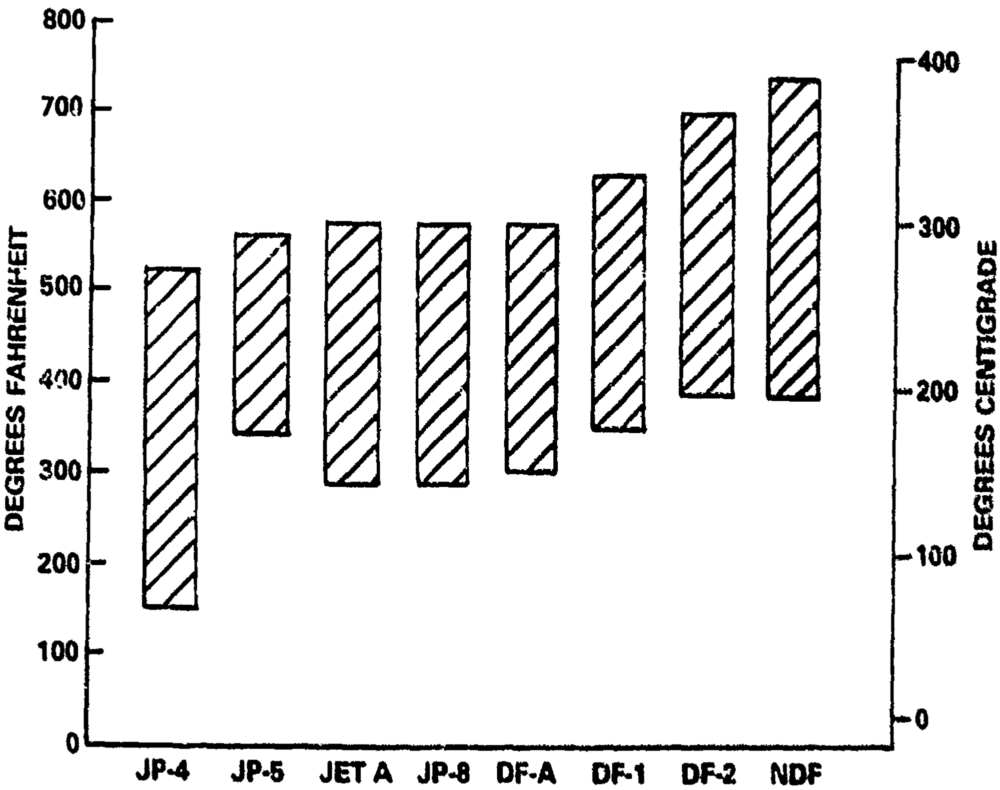

Figure 1. Boiling ranges of fuels

but is not specified for DF-2. The 10 percent point is important in assuring adequate fuel vaporization to initiate combustion. If the 10 percent point is too high, poor engine startability may result.(15) The 10 percent point is controlled for JP-8, which should preclude poor startability (as a result of low volatility) in diesel engines. This effect is important in both diesel and gas turbine engines.

Fuels similar to JP-8 have been and continue to be used year round in cold locations such as Alaska. In fact, U.S. Army General Material and Petroleum Activity (GMPA) has been procuring by way of Defense Fuel Supply Center (DFSC) Jet A-1 for Alaska for the last 5 to 10 years. In gathering data for this report, several locations in Alaska were contacted. It was difficult to gather comparative data from Alaska since sources contacted assumed that DF-1 and Jet A-type fuels that met DF-A specification requirements were used continuously; the use of DF-2 would cause periodic operability problems. When questioned about fuel filter changes, the points of contact indicated that they had no DF-2 experience with which to compare filter change intervals.

The use of JP-8 in cold environments will facilitate the use of some starting aids used on DOD vehicles. Vehicles with airbox or intake-manifold heaters typically pump and burn vehicle fuel using an auxiliary fuel pump (not dependent on engine speed). The excellent cold pumpability of JP-8 should allow the use of these systems in instances where DF-2 fuels would be too viscous to pump and ignite.

Bowden, et al. (16) investigated the effect of reduced viscosity and cetane number on the cold startability of four DOD CI engines. Viscosity of the test fuels ranged from 0.99 cSt to 5.90 cSt at 40°C. Two of the engines exhibited better cold startability using the less viscous fuels.(16) These engines (the Continental Motors LDT-465-1C and the Cummins NHC-250) should benefit from the use of JP-8 in terms of improved cold startability.

Since JP-8 is a less viscous fuel than most DF-2 fuels, it should require less power to run the fuel injection pump. Although fuel injection pump load is a very modest portion of engine output, it is a greater portion of the power required to crank the engine. Under equivalent conditions, the use of JP-8 in lieu of DF-2 may increase cranking rpm of the engine, which can, in turn, have a beneficial impact on the startability of the engine. This impact would be particularly evident at colder temperatures as the viscosity of

DF-2 significantly increases. No comparative data have been found to document this potential benefit.

Work by Likos, et al. (17) at BFLRF has shown less engine lubricant viscosity increase, and lower pentane insolubles were observed at end of test in three of four different engines tested when comparing JP-8 to DF-2. The engine test conditions used for these evaluations were Army/Coordinating Research Council (CRC) 210-hour, NATO AEP-5 400-hour mission profile, and Army/CRC 240-hour test cycles. The cause of the lower viscosity increase and lower pentane insolubles with oil usage is thought to be less soot loading in the used lubricant as a result of cleaner combustion of the JP-8.(17) Part of this effect may be due to the lower maximum power output using JP-8. Less viscosity increase can translate to better engine cold startability since engine oil viscosity plays a large role in cranking rpm, and cranking rpm is a critical parameter in cold startability of diesel engines.(18)

Although vehicle operation in cold weather is of paramount importance, several other aspects of the use of JP-8 in cold weather are worthy of mention. Bulk transport of fuels will also be beneficially affected. Current refinery practice is to heat heavy fuels (such as heating oils) stored in above-ground tanks in order to prevent flow problems upon transfer and reduce wax buildup in the tanks. JP-8, because of its low cloud point and antiwaxing tendencies, will require tank heating at only the coldest of locations. As a result, the energy usage to heat the tanks could be eliminated, which would make the tank farm more reliable during cold-weather transfer operations. Transfer pipes in refineries and storage facilities are often steam-traced or electrically heated in order to prevent flow problems and reduce fluid friction in the pipes. Flow problems can be critical when handling high cloud point products in cold weather; if flow is stopped and the product is allowed to cool, it can be very difficult to get the fuel flowing again. One example of a fuel flow problem occurred in 1977 in Antarctica. An unusual -40°C (-40°F) cold front caused a stoppage of heating oil to the personnel heater and electrical generator of the American base at Palmer Station. The heating oil (specification unknown) was stored in an insulated but unheated tank. The system relied on warm return fuel from the electrical generator to maintain the fuel above its cloud point. The unusually cold weather caused the fuel in the supply pipe to the generator to gel, thus shutting down the generator. Lack of electrical power caused failure of the heating tapes in other areas, thus making it very difficult to restart the generator. Fortuitously,

a 55-gallon drum of fuel stored in the generator shed (at 27°C (80°F)) allowed the generator to be restarted, which permitted the other systems to function again.(19) Although this example of a flow problem is typical of a stationary application, many of the same difficulties are faced by a mobile fleet in cold weather.

The theater petroleum supply system operation could be beneficially affected by the use of JP-8 in lieu of DF-2. All transfer equipment from barges to can-filling equipment should be less likely to be affected by cold weather using JP-8. Horsepower to pump the fuel through pipelines and hoselines will be reduced because the lower viscosity of the JP-8 will produce less viscous drag in long conduits. The lower viscous drag may allow extended distances between boost pumps, requiring fewer boost pumps for a given distance and accruing the benefit of less maintenance on fewer pumps. Operation of pipelines and hoselines in very cold climates would be simplified since a stoppage of product flow due to fuel waxing would not likely plug the conduit. The use of JP-8 may reduce the need for fuel heating systems (such as electrically heated filters and lines) on future military equipment, thus reducing weight, cost, and complexity as well as improving reliability. The fuel heating requirements could be evaluated on an individual basis when considering a developmental item.

Since JP-8 will flow at considerably lower temperatures than DF-2, it may be unnecessary to idle engines in moderately cold climates to avoid engine restartability problems. With the proper lubricant in use and batteries in good shape, the use of prolonged idling (for keeping the engine and fuel system warm) would become unnecessary. Prolonged engine idling is undesirable since it causes detrimental fuel dilution in the engine lubricant, consumes fuel that could be better used for the mission, causes enhanced engine wear, creates nozzle fouling problems, and is detrimental to security-related concealment.(20)

Common practice to prevent water from freezing in fuel systems using DF-2 in cold climates is to add Fuel System Icing Inhibitor (FSII, Ethylene Glycol Monomethyl Ether) to the fuel to preclude ice crystal formation and resultant filter plugging. This product is supplied under a separate national stock number (NSN) in 5- and 55-gallon containers. Since JP-8 already contains FSII, the logistics burden of stocking and handling the FSII is reduced. Additionally, the fire hazard, mixing time, and toxicity concerns of directly handling FSII are eliminated.

Small fuel storage containers such as 5-gallon cans and 55-gallon drums are both susceptible to cold weather exposure. Diesel fuel in these containers in cold weather can be rendered unusable due to transfer problems. Except under the coldest of conditions, the use of JP-8 should eliminate pouring problems from 5-gallon cans and should permit both the standard military 12- and 15-gallons per minute (gpm) hand pumps to be used on 55-gallon drums at much lower temperatures. Also, hand-powered fuel transfer devices could provide a decisive edge in the event of electromagnetic pulse (EMP) affecting electrical devices (such as fuel transfer pumps and power generators). Under moderate temperature conditions, the lower viscosity of the JP-8 relative to DF-2 will require less force to pump a given flow of fuel with the hand pump or will provide a greater flow using the same amount of force. Lower pumping force equates to less operator fatigue when transferring large quantities of fuel.

B. Cleanliness Effects

1. Sulfur

The specification for JP-8 was written to accommodate the special requirements for jet aircraft. As such, JP-8 is a highly refined and clean fuel. One element substantially reduced as a result of the refining is sulfur. The allowable sulfur content for JP-8 is 0.3 mass%, while DF-2 is allowed up to 0.5 mass%. Measurement of 93 JP-8 samples has yielded an average sulfur content of 0.07 mass% with a range of 0.01 to 0.28 mass%.(21) A survey of DF-2 in 1987 in the United States yielded sulfur levels ranging from 0.005 to 0.95 mass% with an average of 0.28 mass% based on 83 samples.(13) The average sulfur content of DF-2 fuels in Europe (and most of the world) is higher than in the United States. Federal Specification VV-F-800D allows sulfur levels of 0.5 mass% maximum for operation in the continental United States (CONUS) and 0.3 mass% for operations outside the continental United States (OCONUS), which essentially represents the NATO environment and hence the somewhat more restrictive sulfur limit due to NATO requirements. The very low sulfur content of JP-8 compared to DF-2 (roughly one quarter) has many advantageous effects for the United States DOD.

The mercaptan sulfur level of JP-8 is limited to 0.002 percent, but DF-2 has no limit on it (as previously noted, it is limited on total sulfur level only). Mercaptan sulfur can have deleterious effects on fuel system elastomers and is corrosive to many metals used

in fuel systems. The use of JP-8 in lieu of DF-2 could have life-lengthening effects for fuel systems as a result of lower mercaptan sulfur contents. Refueling and handling odor will be less due to the lower sulfur content as well as the lower mercaptan sulfur level of the fuel. Technicians at BFLRF with experience in handling both DF-2 and JP-8 report noticeably less odor for JP-8. Additionally, a comment was made that JP-8 fuels are "less oily and less objectionable to clean up."

The low sulfur level in JP-8 may extend exhaust valve life in diesel engines. Chaudhuri (22) states "sulfidation can be an important source of metal deterioration in diesel engine valves under certain conditions." Hot corrosion of exhaust valves appears to be related to the sulfur deposits on the exhaust valves rather than direct contact with gaseous sulfur compounds.(22)

Low fuel-sulfur content should extend the life of lubricants both in peacetime and wartime operations. A lower amount of acid will reach the lubricant as a result of burning less sulfur in the fuel. The additives in the lubricants that neutralize acidic compounds will be effective for a longer time due to the lower rate of sulfuric acid formation in the combustion chamber and resultant piston ring blowby reaching the bulk engine lubricant. In instances where oils are not changed in a timely fashion, the lower rate of acid formation may lead to extended engine life due to less cylinder liner wear. Lower piston ring and cylinder liner wear could be a survival factor in wartime during which oil changes may be infrequent or sporadic.

A study in Norway concluded that aviation turbine fuel is more expensive than conventional diesel fuel, but "we would be able to avoid a portion of these additional costs through reduced maintenance expenditures since this type of light diesel with a low end point and low sulfur content provides good combustion with a cleaner engine and less effect on the motor oil."(23)

In 1983, Detroit Diesel Allison (DDA) recommended that "The sulfur content of the fuel should be as low as possible to avoid premature wear, excessive deposit formation, and minimize the sulfur dioxide exhausted into the atmosphere. Limited amounts can be tolerated, but the amount of sulfur in the fuel and engine operating conditions can influence corrosion and deposit formation tendencies."(24)

The additives used to combat acidity have some adverse side effects in the engine. When burned, some of these additives produce ash and may cause increased deposits on the liner ports and exhaust valves. If concentrations of these additives can be reduced (due to lower sulfur content of JP-8), then engine deposits may be reduced.(24) One recent study found a direct relationship between the level of sulfated ash in the lubricant and the time to exhaust valve failures.(25) Fuel effects on deposits and wear are discussed further in Section III.F.

2. Water and Sediment

Because JP-8 is a highly refined fuel intended for aircraft use, particulate contamination is limited to 1.0 mg/L. Federal Specification VV-F-800D allows up to 10 mg/L of particulate matter in all grades of the diesel fuel. This tenfold decrease in the maximum level of particulate contamination with JP-8 could result in significantly fewer incidents of filter plugging. This effect in diesel engine-powered equipment was reported by aircraft ground service equipment (GSE) operators at the San Antonio International Airport. The ground service equipment is diesel powered and runs year round on Jet A in 24-hour service. GSE service has some similarities to military equipment operations since the equipment spends a large percentage of time idling. One operator reported fuel filter change intervals greater than 1 year.(26) Diesel engine manufacturers represented in this particular fleet were Detroit Diesel Allison (DDA), Cummins, Onan, and Perkins.

The specification for JP-8 includes a water separation index that measures the separability of water from the fuel. Federal Specification VV-F-800D has no water separability index requirement. Fuels contaminated with a surfactant will not pass the water separability test and may poison water coalescers and separators. The use of JP-8 will, therefore, help assure that water coalescers and separators will operate effectively. Water separators and coalescers are necessary for aircraft operation because fuels pick up water and sediment in handling and tankage. A small quantity of water in fuel can disable an aircraft if flow problems are experienced at high altitude and very low temperatures. Although diesel-powered equipment is not as critical of water in the fuel, very clean water-free fuel will preclude any freeze up or startability problems or fuel system and injector corrosion during storage. Water emulsification problems should be eliminated when using JP-8.

Water in diesel fuel increases the fuel's tendency to foster microbiological growth. This growth is most apparent at the water-fuel interface. Microorganisms are numerous and are present in most vehicle and bulk storage tanks. Whether the microorganisms proliferate or not depends on many factors, including temperature, available water, biocides, and degree of stagnation of the water bottom. The growth of microbiological organisms in fuel is undesirable since the organisms can readily clog fuel lines, filters, and injectors, as well as cause steel tank corrosion problems. The use of JP-8 should ameliorate or eliminate any microbiological growth problems since JP-8 typically has a very low water content and contains a Fuel System Icing Inhibitor (FSII), which has proven biocidal properties. The use of JP-8 will not, however, reduce water intrusion from condensation, leaking tanks, rain, poor system housekeeping, or any of the other ways that water finds its way into vehicle or storage tankage.

C. Thermal and Storage Stability

The specification for JP-8 contains both a thermal stability requirement and an existent gum requirement. These tests are designed to prevent the formation of fuel delivery system and engine deposits on hot surfaces. DF-2 destined for long-term storage has an accelerated stability test requirement that is intended to assure the storage stability of the fuel. The thermal stability of JP-8 will, in general, be better than DF-2 because of the highly refined nature of the fuel and because thermal stability is a controlled parameter in JP-8. Although the JFTOT ASTM D 3241 breakpoint (heater tube Code 3 deposit incipient temperature) minimum is 260°C for JP-8, DF-2 fuels generally have breakpoints below 260°C.(16) The improved JP-8 thermal stability should result in lower fuel system deposits in the hot sections of the engine fuel system (primarily diesel injectors and turbine nozzles) and fewer component replacements. In certain DOD power systems where DF-2 would normally be used, kerosine fuels meeting requirements of JP-5/JP-7/JP-8 have been recommended in order to minimize high temperature-related deposits; examples of such use are in primary or standby electric power generating engines in CONUS or OCONUS/remote missile systems.

Poor storage stability of distillate fuels can cause insoluble particulates (both sediment and suspended microparticulates) to form in the fuel. These insolubles can plug filters, foul injectors, form combustion system deposits, and promote corrosion.(27) In respect to unstable diesel fuel, it is stated in Reference 28 that "The unstable test fuel caused

frequent severe vehicle fuel filter plugging, despite the fuel having been prefiltered with a filter having a pore size half that of the vehicle fuel filter." Storage stability can be a very serious problem in military service since, in many instances, fuels have a low turnover rate in large storage tanks or are stored in vehicle fuel cells for extended time periods in prepositioned equipment. Reference 29 describes the kind of diesel fuel stability problems experienced by the Army/DOD, lists 61 specific instances of microbiological and stability-related problems, and has a good bibliography for further study. The excellent storage stability characteristics of JP-8 compared to diesel fuel should lead to fewer stability-related problems. This effect has been recognized for many years by the Army and is evident in the choice of fuel for vehicles stored on Maritime Prepositioning Ships (MPS). JP-5 is now the fuel of choice for these vehicles stored in the fueled state. JP-5 is used instead of JP-8 because the JP-5 has a higher flash-point requirement for shipboard use, the same stability requirements, and an additive package similar to JP-8.(30)

D. Effect of Additives

The MIL-T-83133B specification for JP-8 allows five different types of additives for use in JP-8, which includes Fuel System Icing Inhibitor (FSII), corrosion inhibitor, static electric dissipater, metal deactivator, and antioxidant.

The purpose of the FSII is to prevent the formation of ice crystals when the fuel is exposed to low temperatures. FSII lowers the freezing point of any free water present in the fuel to the point that it cannot freeze. The compound used must conform to Military Specification MIL-I-27686 and is typically ethylene glycol monomethyl ether (EGME).(31) This compound not only acts as an icing inhibitor, but has a biocidal action as well. Use of fuels containing the EGME additive should lower the tendency to plug filters in cold weather and improve the fuel's resistance to microbiological growth. Since the fuel is premixed with the additive, no logistics burden is necessary to supply the EGME. Since microbiological growth can contribute to fuel-system corrosion, the EGME can help reduce corrosion as well. FSII is mandatory in JP-8 and optional in VV-F-800D diesel fuels.

The second additive in JP-8 is a corrosion inhibitor. These compounds must conform to Military Specification MIL-I-25017.(32) A direct benefit of corrosion inhibitors is a

reduction of scale and fine rust shed into the fuel as particulate contamination.(15) Actual corrosion damage to equipment may be less with JP-8 (when compared to fuels not containing a corrosion inhibitor) and provide long-term benefits in equipment replacement. These compounds not only inhibit fuel system corrosion but also improve the lubricity of the fuel. The reduction in the scale and rust should decrease the incidence of filter plugging and reduce wear in rotating equipment used to pump these fuels. The improvement in lubricity is very difficult to quantify in a general way because factors such as viscosity, temperature, contaminants, and equipment type play large roles in determining proper lubrication by fuel. Statements on fuel lubricity are best applied to specific instances. Corrosion inhibitors are mandatory in JP-8. They are mandatory for VV-F-800D fuels intended for use outside the continental United States (OCONUS), but are not required for fuels intended for use within the continental United States (CONUS).

The third additive in JP-8 is the static electric dissipater. Only two formulations are approved at this time. This additive is intended to increase the conductivity of the fuel to within 200 to 600 picosiemens per meter. The friction of fuel moving through a pipe or hose can build up a charge of static electricity that, when discharged, can cause ignition of fuels. The increased conductivity of the fuel minimizes this static buildup by allowing the charge to dissipate to grounded equipment. There is no control over the conductivity of DF-2 fuels. The reduced fire hazard resulting from the conductive fuel is a potential safety benefit from the use of JP-8; however, no safety-related data were found that directly compares the use of JP-8 to the use of DF-2.

The increased conductivity of JP-8 may play a role in fires caused by lightning strikes. Research in this area has been limited mostly to airplanes, and the majority of the work has been done on equipment (such as tanks and meters) rather than fuel. Similarly, no information was found on the effect of electromagnetic pulse (EMP) from a nuclear detonation on fuels stored in tanks. The increased conductivity of the fuel may play a role here as well.

The fourth additive allowed in JP-8 is a metal deactivator. This additive is not mandatory and is intended to passivate metallic materials in fuels that may degrade the thermal or storage stability of the fuel. This additive is typically used in fuels that have undergone a copper sweetening process at the refinery to remove mercaptan sulfur.

Fuels containing the metal deactivator may exhibit better stability characteristics than fuels without the deactivator when stored in fuel systems containing copper or copper alloys. Although the use of copper/copper alloys in DOD fuel systems is discouraged, the fuel-handling system is so extensive that copper continues to be present in many parts of it. The use of JP-8 fuels containing the metal deactivator may interact with this copper more successfully than fuels not containing the additive. Use of metal deactivators is encouraged in VV-F-800D diesel fuels intended for OCONUS or long-term storage. Further, the recently developed MIL-S-53021 Diesel Fuel Stabilizer contains a metal deactivator and an antioxidant component.

The last additive allowed in JP-8 is an antioxidant. Currently 12 compounds are qualified as antioxidants for JP-8. These compounds are to be added to the fuel immediately after processing in order to minimize the formation of gums and peroxides. Antioxidants are mandatory for fuels containing hydrotreated blending components and are optional for fuels without hydrotreated stocks. Fuels treated with the antioxidant should be more stable than equivalent fuels without the compounds. The use of antioxidants is allowed (but not mandatory) in VV-F-800D fuels.

An added benefit of JP-8's additive content would be pilfered or stolen fuel would be easier to trace since few (if any) commercial tanks will contain JP-8. Additive test kits could be the detective tools of fuel policing actions. Also JP-8 is perceived as a thinner fuel (i.e., less viscous) than DF-2; thus, users will be less likely to pilfer it for use in their personal automobiles.

E. Fuel Efficiency and Performance

JP-8 has less available energy per gallon and lower viscosity than DF-2 (see TABLE 2). Because of these decreases, the projected fuel efficiency of JP-8 on a kilometer per liter (miles per gallon) basis (the most commonly recognized fuel efficiency measurement) will typically be less than that for DF-2. Although the maximum engine power is reduced due to reductions in JP-8 fuel energy content and viscosity, the actual net effect is fuel injection and combustion system dependent. This dependency was shown in a BFLRF research program, where three of four engines tested produced higher full-load thermal efficiencies using JP-8 than DF-2. This is to say that the JP-8 performed more efficiently in these engine injection and combustion systems and would, therefore, yield

more kilometers (miles) per Mega Joule (Btu) than DF-2 in vehicles with these engines under maximum power conditions. The increase in thermal efficiency was sufficient to result in improved projected range for vehicles powered by the Cummins NHC-250 and Continental LDT-465-1C engines.(17)

Other research into the effects of JP-8 on vehicle performance was conducted in 1988 by BFLRF.(33) In this work, it was observed that maximum engine power determined by vehicle acceleration rate for JP-8 compared with DF-2 was dependent on specific engine fuel metering/injection system. For example, a 5-ton truck (M928) operating on JP-8 accelerated 5 percent faster than the same vehicle operating on DF-2 fuel. This vehicle employs the Cummins NHC-250 engine discussed in the previous paragraph. It was also observed in this work, that all vehicles tested except the M88A1 medium recovery vehicle had fuel consumption increases with JP-8 that were at or below that predicted by the heating value difference between the two fuels. Another 1988 study (34) of the performance of JP-8 conducted in Spain found a 3.5-percent decrease in the specific fuel consumption (g/kW•h) when comparing JP-8 to DF-2.

Information from France on the comparison of JP-8 and diesel fuel or commercial gas oil in different vehicles was presented by the French representative at a NATO Military Agency for Standardization (MAS) Army Fuels and Lubricants Working Party meeting held in Brussels in June and July of 1987. In one series of tests, eight different vehicles from the motor pool of the Armed Forces Fuel Service (SEA) were compared for fuel consumption. The vehicles fueled with JP-8 accumulated 1,650,000 kilometers (1,025,262 miles) and the vehicles fueled with diesel fuel accumulated 9,850,000 kilometers (6,120,506 miles) of operational data. Fuel consumption differences for all vehicles ranged from a decrease of 3.7 percent to an increase of 5.1 using JP-8. Of the eight vehicles included in this data set, three had better fuel economy using JP-8.(35)

These data (17, 33-35) indicate that the use of JP-8 in lieu of DF-2 may actually result in lower fuel consumption for a given mission than would be expected from fuel energy content values comparisons. However, these data must be tempered with other factors such as engine health, fuel filter efficiency, etc., all of which would affect fuel economy.

F. Deposits and Wear

A low ASTM D 86 50-percent point is desirable to minimize smoke and odor. The 50-percent point is reported for both JP-8 and DF-2, but no limits are placed on it. One reference (15) states, "For example, in high-speed engines, a 50-percent point above 302°C (575°F) might cause smoke formation, give rise to objectionable odor, cause lubricating oil contamination, and promote engine deposits." All JP-8 fuels would fall below this limit.

A low ASTM D 86 90-percent temperature tends to minimize carbon residues (deposits) in the combustion chamber and minimize crankcase dilution. The 90-percent points of JP-8 will fall below those of DF-2 and, therefore, should produce fewer combustion chamber deposits. Lower combustion chamber deposits prolong engine life by causing less wear in the ring-to-liner interface. This effect was demonstrated in a test program that concluded that significantly less wear of the top piston ring was observed, and that fewer combustion chamber deposits were formed using JP-8 in comparison to DF-2.(17) Another test using JP-5 in a single-cylinder version of an AVDS-1790 engine concluded that the JP-5 produced no change to slightly less wear and fewer combustion chamber deposits than DF-2.(36)

The very low average sulfur content of JP-8 has been discussed earlier in this report. An additional benefit from the use of JP-8 in lieu of DF-2 will be the low wear and deposit-forming tendencies of the fuel as a result of the low sulfur content. Many studies have been conducted on the detrimental effects of sulfur on deposits and wear. Cloud and Blackwood (37) reported that an increase in sulfur content from 0.2 to 1.0 percent resulted in a two- to sixfold increase in measured piston ring wear and a two- to fourfold increase in cylinder bore wear. This finding was generally reconfirmed some 30 years later in modern Army two-cycle diesel engine tests at BFLRF.(38,39) Frame (40) references many of the available papers on the deleterious effects of sulfur on deposits and wear. Future investigators may wish to use this work as a starting point.

The specification for JP-8 limits the aromatic content of the fuel to 25 vol%. Although there is no specification limit on the aromatic content of DF-2, its typical aromatic content is approximately 40 percent. Aromatic compounds do not burn as cleanly as other hydrocarbon compounds. For this reason (as well as the lover boiling range

mentioned earlier), fewer combustion chamber and exhaust valve deposits are expected using JP-8 in lieu of DF-2.

G. Visible and Chemical Emissions

There is a great potential to reduce the visible smoke, chemical emissions, and exhaust odor as a result of changing from DF-2 to JP-8. Public transit companies in many parts of the world have recognized this fact and are currently running Jet A-type fuels in many of their urban fleets.(23,41) One study of JP-8 in Spain reported a 43-percent reduction in exhaust smoke using JP-8 in lieu of DF-2.(34) Lower emissions from the use of JP-8 are primarily the result of three property differences between DF-2 and JP-8: 1) lower aromatics content, 2) lower sulfur content, and 3) lower boiling range. Although numerous references discuss smoke and emissions of diesel engines under a variety of conditions, only a limited number are listed herein. Further information may be obtained by examining the references in the referenced papers.(23,41-43)

As previously mentioned, the aromatics content of JP-8 is limited to 25 vol%. An ongoing study by the Coordinating Research Council (CRC) has shown a 0.03 gm/hp-hr reduction in exhaust particulates when the fuel aromatic level was reduced from 30 to 22 vol%.(42) Another study on the effects of fuel volatility and aromatic content on emissions of light-duty diesel engines concluded "Aromatics increases were associated with large increases in hydrocarbons and extractables, and with moderate to large increases in particulate mass emissions. Aromatic increases were also associated with increases in polynuclear aromatic hydrocarbon (PAH) emissions and mutagenic activity as measured by Ames Bioassay."(43) The lower aromatic content of JP-8 is expected to produce not only fewer hydrocarbons and particulates but potentially less mutagenic ones. This effect could be politically important in controlled urban environments (such as California) and a benefit to personnel exposed to diesel exhaust for extended time periods.

The very low average sulfur content of JP-8 will have a positive effect on the particulate emissions of DOD diesel engines. One study concludes "Sulfur-derived particulate accounts for the vast majority of atmospheric particulate from diesel engines. Consequently, fuel-sulfur reduction would have a far greater impact in reducing atmospheric particulate burden than any other diesel engine particulate control strat-

egy."(44) Another study reports a 36-percent drop in particulate emissions as a result of reducing fuel-sulfur content from 0.4 to 0.05 percent.(45) Particulate emissions will be increasingly important as more strict emission standards are enacted. Diesel engine particulates are suspected carcinogens. Reductions in particulate generation may ultimately reduce the risk of cancer to personnel exposed to diesel exhaust for long periods of time.

Reference 46 is excellent for reviewing the beneficial effects of low sulfur fuels. This paper points out that "most of the sulfur in the fuel burns to SO_2, which is emitted to the atmosphere in the diesel exhaust. Because of this, diesels are significant contributors to ambient SO_2 levels in some areas." Reduction of fuel sulfur levels will lower atmospheric pollution levels of SO_2 and may help alleviate acid rain concerns.(46) Reduced acid rain could be a public relations benefit for the U.S. Army/DOD and NATO, particularly in Europe where acid rain concerns for historic structures and vegetation are high.

IV. BENEFITS FROM SINGLE FUEL ON THE BATTLEFIELD

The greatest potential benefit from the use of JP-8 lies in the one fuel forward concept. All aspects of fuel production, procurement, handling, storage, and use will be affected by the use of one fuel (JP-8) rather than three fuels (gasoline, diesel, and jet). Gasoline is being phased out of military service because of flammability hazards.(11) This change is largely complete for tactical/combat vehicles and is progressing for support equipment. The United States Air Force and Army is changing from JP-4 to JP-8 as its primary aircraft fuel.(47) NATO forces as well are moving toward the use of JP-8 as their primary jet fuel.

Interagency procurement of large quantities of JP-8 may reduce the number of personnel necessary to oversee the procurement activity. Manpower needed to oversee the maintenance of multiple fuel specifications will be reduced. Waivers on fuel property deviations should decline since the specification for JP-8 is relatively inflexible. The number of laboratory tests needed to procure fuel will decline since only one specification need be met. Seasonal procurement of fuel will be simplified since there will be no temperature-dependent specification. The right fuel will be delivered to the correct

location since there will be only one fuel. Mix-ups of multicompartmented shipments will be minimized for military deliveries. Disposal of aged or out-of-season fuel should be essentially eliminated since JP-8 ages well and is not changed seasonally. With the larger volume of fuel usage associated with one fuel, it may be feasible to optimize the output of some refineries to produce JP-8 more efficiently. NATO procurement activities will be easier to coordinate with CONUS and OCONUS procurement activities since all will share a common fuel specification. Procurement and logistics of support products (examples: FSII, high and low total base number (TBN) lubricants, etc.) necessary for the handling and use of multiple fuels will be reduced or eliminated.

Accounting systems for fuel usage will be somewhat simpler since only one fuel price need be taken into account. Fewer NSNs for fuel and support supplies will be required. Fewer volume correction errors should occur during custody transfers since the formula will be relatively standard.

Handling of one fuel rather than three will prove beneficial in both peacetime and war. In bulk transport systems, there will no longer be any doubt as to which product is to be delivered. Fuel logistics will be simplified from how much of what, where, and when to how much JP-8 where and when. Combined tankage for combined exercises (Air Force, Army, Marines, Navy, NATO) would further simplify logistics. Layout and operation of petroleum supply points in theaters of operation may be optimized since it will be easier to shift fuel to the dispensing facility that requires it. Air support for convoys will be able to refuel directly from convoy supplies rather than returning to base for refueling. Field commanders will be able to allocate fuel to equipment required for the mission, regardless of the kind of fuel available. This capability will lead to fuller utilization of fuel and eliminate pockets of unusable fuel (example, diesel fuel reserves unusable by aircraft). Fuel from damaged or inoperable equipment will be usable in all other equipment. All prepositioned fuel supplies will be usable by all equipment, simplifying the logistics associated with troop movements.

Purging of hoselines and pipelines to eliminate the interface between dissimilar fuels will be eliminated. Disposal or accidental spillage of the interface will be eliminated, which is beneficial not only from a time and materiel standpoint but from an environmental standpoint. As a result, the after effects of a pipeline or hoseline deployment could be ameliorated, which would contribute to better acceptance of exercises by civilian communities.

Field labeling or relabeling of fuel containers will be eliminated since there will be only one fuel. Vehicles will not be fueled with the wrong fuel (such as gasoline) or with a summer-grade fuel in the winter time. Training of new personnel will be simplified since only one set of fuel precautions and handling procedures need be communicated.

With the use of one fuel, there exists the long-term possibility of further standardization of fuel transfer and filling fittings for all United States and NATO forces. This standardization would not only promote interoperability of forces but would minimize parts inventory and associated logistics.

Since the properties of JP-8 are closely controlled, the effects of climatic conditions on fuel handling can be accurately predicted. As a result, the possibility of a heavy diesel fuel shutting down operations in the event of an unexpected cold snap would be eliminated.

V. CONCLUSIONS

Many potential benefits are associated with the exclusive use of JP-8 as a single fuel in Army/DOD ground equipment. This report has attempted to briefly discuss these benefits and provide references for further study. Some of the benefits associated with the use of JP-8 will be immediate, while others will require time to be appreciated and quantified. Some benefits will accrue during peacetime operations, and some will be most useful during times of conflict. As JP-8 finds increasing use in field tests and conversion of military bases, some problems may become evident in addition to the benefits. Careful weighing of the benefits and penalties will ultimately lead to optimal usage of fuel resources and, hopefully, increased readiness. The main benefits associated with the use of JP-8 in DOD diesel equipment are:

- **Simplified Logistics.** This effect will be most useful during wartime, but has peacetime benefits as well. This benefit will become increasingly apparent as JP-8 is more extensively utilized.

- **Increased Readiness.** All vehicles and equipment will be fueled with the correct fuel regardless of location or climatic changes. As missions change or redeployment is required, the fuel will stay the same. Fewer unscheduled

maintenance problems relating to corrosion of fuel-wetted interior surfaces/components, fuel filter plugging, and fuel injector/nozzle fouling should result.

- **Reduced Emissions.** Reductions in both visible and chemical emissions may reduce visible signature and prove environmentally beneficial. The political ramifications of these lower emissions are far-reaching.

- **Lower Effect on Engine Lubricant Degradation.** Increased engine lubricant life and the potential for longer time between oil-wetted engine component overhauls are potential benefits.

VI. RECOMMENDATIONS

The current and future benefits derived from using JP-8 should be quantified. A useful JP-8 demonstration program would be operations that involve joint forces, to include Army ground and aviation activities. These operations should be monitored for benefits as well as possible problems and the lessons learned applied accordingly.

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LIST OF ABBREVIATIONS

AD	Defense Technical Information Accession Number
AFLRL	Army Fuels and Lubricants Research Laboratory
ASTM	American Society for Testing and Materials
AVIA	Aviation
BFLRF	Belvoir Fuels and Lubricants Research Facility at SwRI
Belvoir RDE Center	U.S. Army Belvoir Research, Development and Engineering Center
Btu	British Thermal Unit
C	Centigrade
CI	Compression Ignition
CONUS	Continental United States
CRC	Coordinating Research Council
cSt	Centistoke
CUE	Cooperative Universal Engine
DDA	Detroit Diesel Allison
DF	Diesel Fuel
DOD	Department of Defense
EGME	Ethylene Glycol Monomethyl Ether
EMP	Electromagnetic Pulse
F	Fahrenheit
FSII	Fuel System Icing Inhibitor
FTP	Federal Test Procedure
g/kW·h	Grams per Kilowatt Hour
gm/hp-hr	Grams per Horsepower Hour
gpm	Gallon Per Minute
JP	Jet Propellant
L	Liter
MAS	Military Agency for Standardization (NATO)
max	Maximum
mg	Milligram
MJ	Mega Joules
MPS	Maritime Prepositioning Ships
NATO	North Atlantic Treaty Organization

ND	Not Determined
NDF	Naval Distillate Fuel
NE	No Equivalent
No.	Number
NR	No Requirement
NSN	National Stock Number
OCONUS	Outside the Continental United States
PAH	Polynuclear Aromatic Hydrocarbons
rpm	Revolutions per Minute
SAE	Society of Automotive Engineers Inc.
SEA	Armed Forces Fuel Service (France)
STP	Special Technical Publication
SwRI	Southwest Research Institute (San Antonio, Texas)
U.S.	United States
vol	Volume
wt	Weight

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